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Design and implementation of a maritime conflict prediction system

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Design and Implementation of A Maritime Conflict Prediction System

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Abstract

Maritime conflicts have serious impacts on Singapore and the surrounding region both economically and environmentally. This is particularly severe for conflicts such as collisions between large vessels or tankers carrying oil and chemicals. Thus, it is in the interests of the Maritime and Port Authority of Singapore (MPA) to avoid collisions or near-collisions among such vessels navigating through Singapore waters. Existing systems used by MPA predict potential maritime conflicts arising within a short and fixed time horizon. The system produces inconsequential warnings that are often ignored. In this paper, we describe an advanced computer-based system designed to assist in the prediction of potential maritime conflicts of sensitive vessels on Singapore waters.

1 Introduction

Singapore suffered its worst oil spill on October 15 last year when the Very Large Crude Carrier Orapin Global collided with the Evoikos, an oil tanker half its size, spewing 28,463 tonnes of oil into the sea around the southern islands. The oil spill took 650 men and 80 boats working 16-hour days three weeks to clean up. In all, 16,500 bags of oil sludge were removed from the shores of the southern islands [1, 2, 3, 4].

Oil spills have serious impacts on Singapore and the region economically and environmentally. There is lost revenue due to the interruption of port activities. Large amounts of human and hardware resources are required to clean up the spill. Environmentally, an oil spill pollutes and toxicates marine and biological lifeforms. In the recent spill, an assessment by the Nature Society of Singapore found that whole stretches of mangrove, about fifty metres wide, which surround some of the southern islands, appear to be dead.

The Maritime and Port Authority of Singapore designates a class of vessels as *sensitive* vessels: Very Large Crude Carriers (VLCC), Liquid Petroleum and Gas (LPG) tankers, Liquid Nitrogen and Gas (LNG) tankers, and Cruise Liners. When these vessels navigate through Singapore port waters, it is in the interests of MPA to avoid collisions and/or near-collisions among such vessels as much as possible.

Presently, MPA maintains a Vessel Traffic Information System (VTIS) that provides a function for predicting potential maritime conflicts within Singapore port waters. However, the prediction is made at a time horizon of only eight to ten minutes. It will be useful for the Port of Operations Control Centre (POCC) if the prediction can be done at a variable time horizon, ranging from ten minutes to three hours.

A Conflict Prediction System (CPS) is proposed to assist in the prediction of potential maritime conflicts at variable time horizons; to issue warnings when such conflicts are predicted; and to supply pre-defined strategies for reference in the resolution of conflicts. It is envisaged that CPS be capable of receiving input vessel information from MPA's current VTIS so as to afford real-time conflict prediction. It is anticipated that CPS will enhance maritime safety and further improve the manageability of vessels in Singapore port waters.

The organization of this paper is as follows: The next section describes the current physical organization of maritime space around Singapore ports and presents a brief overview of the mode of operation involving vessels entering and leaving Singapore ports. In Section 3, we give an overview of the CPS system and describe the conflict prediction algorithm. Finally, the last section concludes the paper with a brief summary of the extensions for future work.

2 Background

This section describes the current physical organization of maritime space around Singapore ports and presents a brief overview of the mode of operation involving vessels entering and leaving Singapore ports.

2.1 Physical Maritime Space

There are four pilot boarding points, eleven fairways and channels, and five critical regions within Singapore maritime space that are taken into consideration in the design of the Conflict Prediction System (CPS).

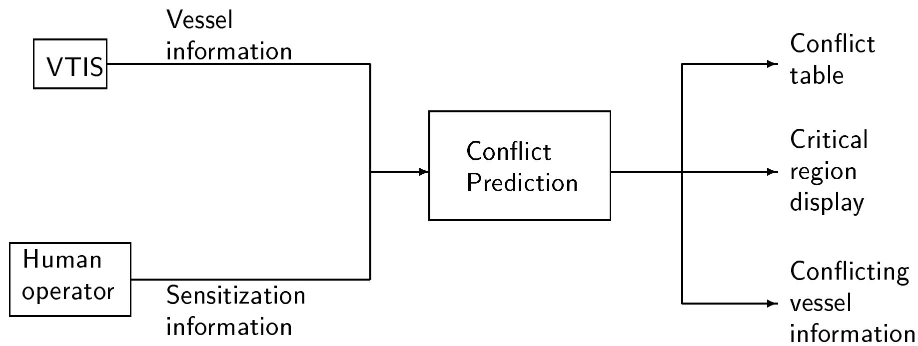

Figure 1: System organization.

A pilot boarding point is a predefined location where MPA's pilot boards another vessel. This happens when a vessel enters and leaves a port. Four such points are to be included in CPS, namely, Singapore Western Boarding Ground, Singapore Southern Boarding Ground, Singapore Eastern Boarding Ground A, and Singapore Eastern Boarding Ground B.

Fairways and channels are geographic regions supporting two-way maritime traffic. They correspond to lanes on highways. Vessels keep to the right when moving through them. Eleven fairways and one channel are to be included in CPS, namely, West Jurong Fairway, East Jurong Fairway, Sultan Fairway, Sinki Fairway, Pesek Fairway, West Keppel Fairway, East Keppel Fairway, Sisters Fairway, Eastern Fairway, Jong Fairway, Southern Fairway, Phillip Channel.

Presently, MPA identifies five critical regions where potential conflicts may occur. A critical region is a geographic area of water adjoining two or more fairways or channels. It may overlap areas constituting fairways or channels. In a critical region, vessels from one fairway navigate to another fairway and this may result in potential conflicts. Five critical regions are to be included in CPS, namely:

1. A section of the Phillip Channel adjacent to the Singapore Eastern Boarding Ground A. The closest fairways are the East Keppel Fairway and the Southern Fairway.

2. A section of the Phillip Channel adjacent to the Singapore Southern Boarding Ground. The closest fairways are the Jong Fairway and the Southern Fairway.

3. A section of the Phillip Channel. It is closest to Pulau Senang.

4. A section of the Phillip Channel near the Singapore Western Boarding Ground. The closest fairways are the Sultan Fairway and the Sinki Fairway.

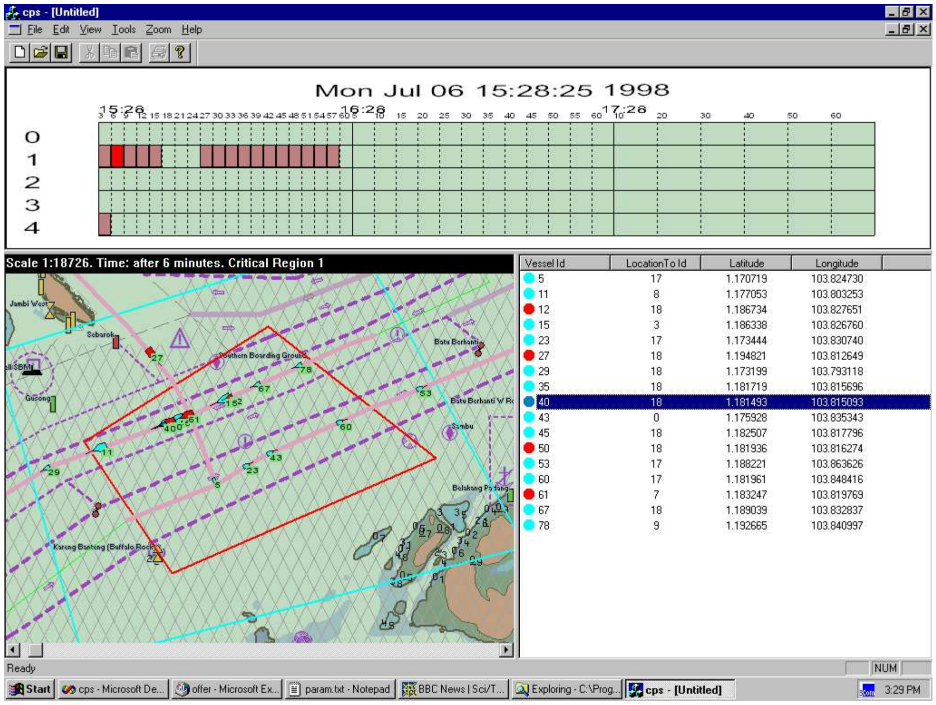

Figure 2: Graphical user interface for Conflict Prediction System.

5. A section of water at the intersection of the East Jurong Fairway, the West Keppel Fairway, and the Sinki Fairway.

2.2 Mode of Operation

When an incoming vessel approaches Singapore port waters, it informs MPA of the estimated time to reach a pilot boarding point. The actual time when it arrives generally deviates from the estimated time by no more than fifteen minutes. This information is recorded by MPA.

When a vessel stops at the pilot boarding point, MPA's pilot boards the vessel and steers it to either a berth or an anchorage. The estimated time to reach the destination is to be provided to and recorded by MPA. The estimation is accurate to within fifteen minutes.

An outgoing vessel notifies MPA about ten minutes ahead of the time of its departure. It informs MPA of the estimated time it takes to reach a pilot boarding point.

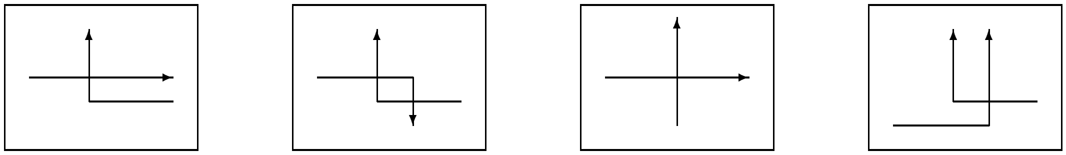

Figure 3: Conflict situations.

2.3 Current Situation

MPA is particularly interested in the safety of identified sensitive vessels. However, currently the prediction is made for *all* vessels within the radar coverage with very little lead time. This results in too many false alarms and it is not possible to perform focused and isolated prediction on selected vessels. Hence, MPA requires a system that will perform conflict prediction, issue warning, and suggest conflict avoidance strategies on selected vessels in the five critical regions (described in Section 2.1).

3 System Overview

Figure 1 gives an overview of the system. The inputs and outputs of the system are described below. Figure 2 shows the graphical user interface for CPS. The user interface is designed to allow MPA to monitor the safety of five critical regions in a given time frame (three-hour lookahead with respect to the current time).

3.1 Input data

CPS receives vessel information from VTIS at a regular interval of about five seconds. These information are captured by VTIS's radar. Generally, there are about 300 to 500 vessels at any time instance. For each selected vessel, the following information is required: vessel identification, vessel type, location, speed, bearing, destination.

An inbound vessel navigates through a sequence of paths from the time its location is picked up by the radar until it anchors at a port (destination). At any time instance, only the current path is known of each vessel. When a vessel reaches the end of a path, the next path must be identified and informed.

Presently, only a subset of vessels are selected for conflict prediction. These are sensitive vessels identified by MPA. The user interface also allows MPA operators

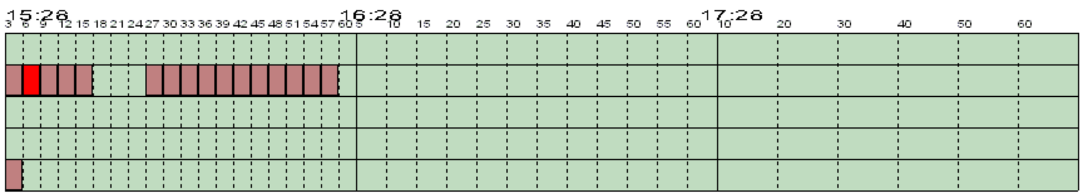

Figure 4: Conflict result table.

to select a subset of vessels to be included for conflict prediction. This process is referred to as *vessel sensitization*.

3.2 Processing engine

With the inflow of latest vessel information from VTIS, CPS predicts potential conflicts in the next three hours (from the current time). A potential conflict is a scenario arising within a critical region at a particular point in time whereby the extrapolated paths of two or more moving selected vessels intersect in the region. It is undesirable because these vessels may collide with one another. We identify four conflict scenarios as shown in Figure 3. In each scenario, the (directed) paths of two or more sensitized vessels cross in a critical region.

CPS determines potential conflicts that may happen between the current time and three hours into the future. This computation is performed continuously at an interval of three minutes. The prediction algorithm works as follow:

```
foreach TimeUnit t {
    foreach CriticalRegion k {
        foreach Vessel i, j in Region k {
        if (path[i] conflict with path[j])
            set conflictTable[t][k] = TRUE;
        }
    }
    foreach Vessel i {
        do updateVessel(i);
    }
}
```

For each time unit (three minutes) from now (current time) until three hours later, the conflict status in each critical region is determined. If a conflict exists between some vessels in a critical region at some point in time, it is recorded. At the end of each run, the status of each critical region is shown graphically (Figure 4).

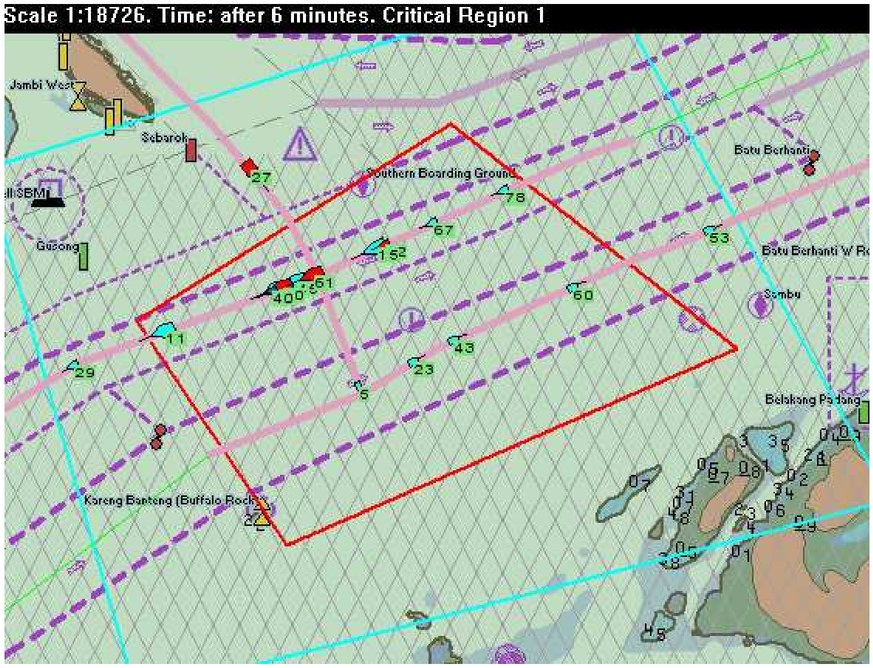

Figure 5: Vessels in a critical region.

3.3 Output results

The output of the prediction algorithm is a two-dimensional table as shown in Figure 4. The vertical axis has an entry for each critical region. The horizontal axis begins with the current time and extends three hours into the future. It is subdivided in intervals of three minutes (for the first hour), five minutes (for the second hour), and ten minutes (for the third hour). Each cell blob in the table indicates whether a conflict has been predicted to occur.

When a cell blob indicating a predicted conflict is manually 'clicked' by an operator, a graphical visualization of conflicting vessels in the critical region is shown. Figure 5 shows an example. The list of conflicting vessels and their information is also shown in a table (Figure 6).

3.4 Implementation Status

CPS is implemented on a Pentium PC running Windows NT operating system. Development is done on Microsoft Visual C++. At the point in which this paper is written, most of the modules have been implemented, and integration with VTIS is on its way.

Vessel Id	LocationTo Id	Latitude	Longitude
5	17	1.170719	103.824730
11	8	1.177053	103.803253
12	18	1.186734	103.827651
15	3	1.186338	103.826760
23	17	1.173444	103.830740
27	18	1.194821	103.812649
29	18	1.173199	103.793118
35	18	1.181719	103.815696
40	18	1.181493	103.815093
43	0	1.175928	103.835343
45	18	1.182507	103.817796
50	18	1.181936	103.816274
53	17	1.188221	103.863626
60	17	1.181961	103.848416
61	7	1.183247	103.819769
67	18	1.189039	103.832837
78	9	1.192665	103.840997

Figure 6: Information of vessels in conflict.

4 Conclusions

CPS is a system designed to assist MPA operators in the prediction of potential maritime conflicts at variable time horizons. The system receives real-time vessel information from MPA's current VTIS and predicts potential conflicts occurring in each critical region in the next three hours. It is anticipated that CPS will enhance maritime safety and further improve the manageability of vessels in Singapore port waters. Various extensions may be made to enhance the functionality and utility of the system:

- A simulation module that generates maritime hypothetical scenarios and simulates the operation of CPS under these scenarios. The objective is test, gauge and understand the capability of MPA in handling such scenarios. Thus, it can be used as a planning tool.
- An integration of CPS with other experimental systems (such as the Anchorage Management System, Sea-Space Capacity Modelling System) to provide a unified approach in equipping MPA with the necessary advanced technologies for port management in the next century.

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